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ABSTRACT

This module is the eighth in a series of eleven modules in an energy conservation curriculum for secondary and postsecondary vocational students. It is designed for use by itself or as part of a sequence of four modules on conservation in building construction and operation (see also modules 9-11). The objective of this module is to train students in the recognition, implementation, and utilization of energy consumption and possible conservation in building construction and design. First, an introduction to the module and definitions of key terms are provided. Next, the text is presented in the following four units: (1) construction considerations before building; (2) building site and design; (3) weatherization; and (4) weatherization student workbook. The information in the first three units is presented in lecture format accompanied by laboratory exercises and questions/examples for class discussion. A bibliography and several charts/tables illustrating the text material are found at the end of the module. (BM)

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Energy Conservation Curriculum for Secondary and Post-Secondary Vocational Students. Module 8

BUILDING CONSTRUCTION VERSUS ENERGY CONSERVATION

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NAVARRO COLLEGE
CORSICANA, TEXAS

April, 1979

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MODULE #8

BUILDING CONSTRUCTION VERSUS ENERGY CONSUMPTION

This module is one of a group of 11 modules in an energy conservation curriculum for secondary and post-secondary vocational students. BUILDING CONSTRUCTION VERSUS ENERGY CONSUMPTION may be offered by itself or as part of a sequence of three modules in the following order:

Order	Module	Title of Module
1	8	Building Construction Versus Energy Consumption
2	10	Heating, Ventilating, and Air Conditioning Conservation Opportunities
3	11	Economics of Energy Conservation

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MODULE #8

BUILDING CONSTRUCTION VERSUS ENERGY CONSUMPTION

MODULE DESCRIPTION:

This module discusses heat transfer in buildings, such as heat conduction, convection, radiation, and evaporation. Heat loss and heat gain characteristics and values are discussed in terms of air infiltration, glazing, insulation, and thermal mass. Building site selection, orientation, and shading, as well as building codes and regulations, are presented as considerations necessary prior to construction.

Calculating heat loss and gain, while utilizing weather data and discussing cost and benefit analysis of conservation opportunities, makes up a major portion of this module. A student workbook for surveying heat loss and heat gain in a home is provided along with formulas to determine costs and savings for implementing certain energy conservation measures.

GOAL STATEMENT:

The objective of this module is to train secondary and post-secondary students in the recognition, implementation, and utilization of energy consumption and possible conservation in building construction and design.

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UNITS:

1. Construction Considerations Before Building
   - A. Home Energy Consumption
   - B. Home Energy Conservation Potential
   - C. Methods of Transferring Heat
   - D. Building Codes
2. Building Site and Design
   - A. Orientation
   - B. Glazing
   - C. Insulation
     - 1.) The K Factor
     - 2.) The U Factor
     - 3.) The R Factor
     - 4.) Types of Insulation
   - D. Walls
   - E. Ceilings
   - F. Shading Devices
   - G. Building Mass
3. Weatherization
   - A. Windows
   - B. Doors
   - C. Caulking
   - D. Energy Conservation Measures
     - 1.) During the Heating Season
     - 2.) During the Cooling Season
4. Weatherization Workbook

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MODULE #8

BUILDING CONSTRUCTION VERSUS ENERGY CONSUMPTION

TERMINOLOGY

British thermal unit (BTU) - a measurement of heat energy. The amount of heat energy required to raise the temperature of one pound of water one degree Farenheit. Furnances and air conditioners are sized in British thermal units.

Condensation - water that forms from water vapor in the air. When the temperature of the air drops, some of the water vapor in the air will change into water.

Conduction - a method of heat transfer. Heat is transferred when a warm object touches a cool object. The term also refers to the passage of electrical current.

Convection - a method of heat transfer. Moving air picks up heat from nearby objects and transfers it to cool objects.

Cooling load - also called heat gain. The amount of heat energy that enters a structure during the cooling season.

Degree day - a measure that expresses the average temperature difference relative to 65 F during a 24 hour day. If a certain day has an average temperature of 30 F, the degree days would be 35. Degree days are used to calculate heating and cooling loads and building requirements.

Design temperature - the hottest or coldest temperature in an area. Used for sizing heating and air conditioning systems.

Effect temperature - the total effect on the comfort of the human body of air movement, humidity, and temperature.

Evaporation - the process of a liquid changing to a gas. Water changing into water vapor is an example of evaporation.

Heat gain - the amount of heat energy that enters the house from outside sources. Usually used in reference to summer cooling, but additional heat from outside sources during the winter is also heat gain. Often called cooling load.

Heat load - also called heat loss. The amount of heat lost through the structure of a building. Heat loads are measured in BTU per hour.

Heat loss - see heat load.

Heat transfer - the movement of heat energy.

Infiltration air - air that comes into a house unintentially through cracks and openings in the structure.

Insulating glass - windows with two panes of glass sealed together in one sash. The extra air space between the panes reduces the heat flow through the window area.

Insulation - material that does not readily conduct heat energy.

Jamb - the top and sides of a door or window frame that make contact with the door or the sash.

Joists - the parallel framing boards that support the floor and ceiling. The joists run horizontally.

K factor - a number indicating the amount of heat energy that will pass through a material. Also called the conductivity factor.

Loose fill insulation - insulation that is bought in a sack and poured into place.

Mineral wool - a material used to make insulation including loose fill insulation and insulation batting.

Polystyrene - a closed-cell, plastic foam insulation with a high thermal resistance.

Radiation - a method of heat transfer. Infrared rays warm an object without contact from objects or air.

R factor - the resistance of a material or an entire wall to the flow of heat. Insulation is rated in R values to show its resistance to heat flow.

Sash - the frame holding the glass in a window.

Sheathing - the boards that cover the framing of a structure on the walls and roof.

Solar heat - Heat from the sun.

Solar load - the number of BTU's added to the cooling load of the structure by the sun.

Studs - the parallel vertical boards that form the wall supports of a structure.

Subfloor - the boards laid on top of the floor joists. The subfloor is between the finished floor and the floor joists.

Sweating - the formation of moisture droplets on a cold surface when it comes in contact with warmer air.

Temperature, design - the hottest or coldest temperature in an area. Used for sizing heating and air conditioning systems.

Temperature difference - the difference in temperature between the inside and the outside of a home.

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Therm - a unit sometimes used for selling natural gas. One therm equals 100,000 BTU's.

Threshold - a wood, metal, or vinyl device that fills the space at the bottom of a door.

U factor - a number indicating the amount of heat that will pass through a wall. The U factor is a composite of the K factors of the individual materials in the wall.

Vapor barrier - a material that prevents moisture from passing through or condensing on the walls of a structure.

Weather stripping - strips of material designed to be installed around doors and windows to stop the flow of air.

Weep hole - the hole in the bottom edge of a storm window that allows moisture to drain from the enclosed space.

MODULE #8

BUILDING CONSTRUCTION VERSUS ENERGY CONSUMPTION

UNIT 1

CONSTRUCTION CONSIDERATIONS
BEFORE BUILDING

OBJECTIVES: Upon completion of this unit the student will be able to:

1. Recognize energy conservation potential in home building and remodeling.

2. Discuss and recognize the importance of building codes and the problems associated with them.

3. Discuss and recognize the three types of heat transfer.

LECTURE

INTRODUCTION

In many instances people involved in writing energy conservation codes and standards fail to consider the overall design of the house with respect to energy saving practices. They will specify that a certain amount of insulation be installed in the walls and ceiling of houses in certain areas of the country. This makes no sense, since it penalizes the builder who uses good design (proper orientation, small glazing area, etc.) by requiring that he install the same insulation as is installed in a poorly designed house.

Many design and construction features exist which the builder can incorporate into new homes in order to reduce energy consumption. Not all of these features will add to first cost. In fact, some of the most significant features in terms of BTU's saved, such as less glass area, will reduce first cost. These various design features will be discussed in this module and the poten-

LABORATORY

Unit 4 at the end of this module is intended as a workbook for student use. It can be discussed throughout the module in relationship to the lecture material.

tial energy savings will be explained. The design features that will be discussed are those that apply to single family housing but not necessarily to other types of light residential construction.

A. HOME ENERGY CONSUMPTION

In order to be able to build better energy conserving homes, it is important to understood what combination of design, operation and construction result in the greatest energy use so that conservation efforts can be concentrated where they will do the most good. Generally, the greatest energy savings in residential buildings can be attained through reduction of air infiltration, primarily related to windows and doors, followed closely by the reduction of conductive heat transfer through the walls and windows.

In Report No. HUD-HAI-2 Residential Energy Consumption, Single Family Housing, March 1973, prepared by Hittman Associates, Inc., Columbia, Maryland 21045, detailed theoretical quantitative thermal analyses were performed on typical single-family residences in the Baltimore/Washington area. This study revealed a distribution of heating and cooling loads by major components as shown in Figure 1.1.

FIGURE 1.1 BREAKDOWN OF HEATING AND COOLING LOADS FOR CHARACTERISTIC HOUSE USED IN HUD STUDY

COMPONENTS	% OF HEATING LOAD	% OF COOLING LOAD
CEILING	3.7	2.3
FLOOR	2.2	2.4
TOTAL WINDOW	13.6	4.1
TOTAL DOOR	1.4	0.4
TOTAL WALL	23.9	14.2
INFILTRATION LOAD	55.2	41.5
INTERNAL LOAD	--	35.1
	100.0	100.0

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As can be seen, the infiltration load was 55.2% and 41.5% for heating and cooling respectively. Also of significance is the fact that the internal load, i.e., appliances, lights, and occupants, was 35 percent of the cooling requirements. Analysis of the internal load showed that 25 percent of the heat gain was from the occupants, 19 percent from the lights, and 56 percent from appliances.

Heating requirements measured in this study were interpreted in terms of primary energy requirements by use of a gas fired furnance. Cooling requirements were interpreted in terms of primary energy requirements by use of an electrically-driven central air conditioning unit. Heating and air conditioning will not be discussed in this module. For specific discussion on heating and air conditioning refer to module #10 of this series.

B. HOME ENERGY CONSERVATION POTENTIAL

From the data mentioned above, it can be seen that a great potential for energy conservation lies in the design and construction of a house, particularly with regard to reducing the infiltration load. Dozens of design and construction features can be incorporated into new homes to reduce energy consumption. However, there may be problems in doing so. First, there is a lack of cost versus energy saving data on many of these features. Second, many worthwhile energy saving design features in one part of the country may not be so in another part. It is likely, however, in view of the rapidly rising energy costs, that most of the items mentioned in this unit will be economically advantageous in the long run.

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Metered tests on energy consumption for heating have shown that the amount of energy used for heating a house is not necessarily related to the design heat loss of the house. The biggest single influence on heating energy consumption is the occupants themselves. Identically built adjacent houses can easily have heating energy consumption variations of 50% due to occupant life style. Consumer operating procedures is, therefore, another important area of potential energy saving. Numerous operating procedures can, and should, be encouraged to reduce energy consumption. Substantial energy savings can be realized by educating the homeowner to more efficiently operate his dwelling. Before discussing building construction it is important to understand the principles of heat transfer through conduction convection, radiation, and evaporation.

C. METHODS OF TRANSFERRING HEAT

Heat energy is moved or transferred from one place to another chiefly by three methods: conduction, convection, and radiation. All homes are heated or cooled using at least one of these methods. The reason it is important to know something about them is that they greatly affect the efficiency of your heating and cooling equipment. When the transfer of heat becomes inefficient, it costs you more to heat and cool your home.

Conduction simply means heat is transferred by direct contact. When you place a pot on the burner of your stove, the heat energy is transferred from the burner to your pot. If the stove is electric, the pot rests directly on top of the heating coil. If the stove is gas, the flame touches the pot. In either case, the conduction requires

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a good contact between the source of the heat and the object to be heated. Dirt and soot between the source and object can destroy the efficiency of heat conduction in a furnace by acting as an insulator to slow down the transfer of heat. On the other hand, good insulation in your home can reduce the heat load and heat gain.

Convection simply refers to the heating or cooling of liquids and gases. When heating a gas such as air, the air molecules are free to move about and mix together. Warm air rises and cool air sinks, but the air currents that are created in this way tend to churn and mix the air so that its temperature becomes nearly uniform. Some conduction heating does take place, but the mixing or convection process dominates. The cool air drawn into a gas furnace is heated by convection in the burner box. Similarly, a baseboard electric heater draws cool air in at the bottom, where it is heated by convection as it passes over the hot fins inside, and then the entire room is heated by convection as the hot air rises and circulates throughout the room. Steam and hot-water furnances also use the principle of convection heating. Air conditioners use a more complex process involving Freon on the inside, but heating and cooling the air on the outside works by simple convection. The efficiency of convection heating and cooling is reduced by dust and dirt and by restrictions that slow the circulation of the air.

Radiation is the third method of heat transfer and it differs quite a bit from either conduction or convection. The best example of radiation is sunlight or solar heat. When you stand out in the sun, rays of heat energy from the sun warm

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your body. But only that part of your body exposed to the sun is actually warmed by radiation; the shaded part is not warmed at all. Radiation is also at work when you stand in front of a fireplace or any other very hot source of heat. Heat lamps and even ordinary light bulbs give off heat radiation. Anything that is hot enough will emit infrared (heat) radiation, though it doesn't have to be hot enough to glow or give off light. The important characteristic to remember about radiation is that it always travels in a straight line; it cannot go around corners. However, heat radiation can be reflected just as light can, so shiny and light-colored surfaces can be used to reduce the heating effect of radiation. Radiation heat can be very effective in some applications, and it is the main principle behind the operation of electric and gas-fired space heaters.

Another method of heat transfer deserves mentioning, although it is readily a combination of conduction and convection. Evaporation is an important form of heat transfer that enters into most heating and cooling operations. Both water and water vapor may feel just as warm to you when they are at the same temperature, but the fact is that water vapor contains more heat energy. Thus, as water evaporates, the vapor draws heat energy out of the remaining water, making it cooler. Furnace humidifiers use heat energy in humidifying the air, but the air feels warmer and much more comfortable, making it possible to turn the thermostat down a couple of degrees.

Evaporation works both ways, however. For in order to condense the water vapor from the air, the extra heat energy must be removed from the water vapor to turn it back into water. In fact, an air conditioner has to work almost as hard to reduce the humidity of the air by one percent as it does to reduce the temperature of the air by one degree. That is why it is so important in summer weather to use an exhaust fan to remove steam from cooking and showers, rather than to make the air conditioner work extra hard to remove it. The exhaust fan is a much cheaper way to cope with water vapor.

D. BUILDING CODES

Another consideration before building is that of building codes. A building code is intended to set minimum construction standards so as to protect the health and safety of building occupants. Codes control such diverse things as property setback limits, areas of rooms and windows, sizes and spacing of structional members, and design requirements for stairways and exits. Separate codes are usually written to cover plumbing and electrical wiring. The more recent and progressive codes are written on a performance basis, which means that they state the desired ends rather than the exact means of achieving them. An example would be a code requiring a floor construction capable of carrying a load of 40 pounds per square foot as opposed to one which specifically lists the various materials and spacings of structural members that are acceptable. The first will allow new or different types of construction, while the latter is merely a rubber stamp for the status quo.

The ideal solution would be to have one national code which applied everywhere. The electrical industry has pretty well succeeded in getting

The student should use Figure 1.2 to learn about the building codes in his/her city or town. Contact the local building contractors or building inspectors to gain details of building codes in your area.

the National Electrical Code adopted uniformly throughout the country. The National Plumbing Code is also widely used, but is by no means universal. Three different major attempts have been made to create a national code which covers building construction. Unfortunately, the results were just three more codes. Since writing a good code is an extremely expensive and complicated task, few smaller states or cities write their own. They merely adopt one of the so-called "national codes" with or without their own modification. The three "national codes" are the National Building Code, the Southern Building Code, and BOCA (Building Officials' Code of America), normally pronounced as one word, "Boca." The latter code is the most progressive and, fortunately, the most widely adopted.

How do you tell which code, if any, you should follow? Normally, the local government unit--city, town, village, or county--administers whatever code is used. In many instances, even though there may be a state code, it is up to the local community to set up enforcement of the code through a building inspector. If the community doesn't have an inspector, there is no way it can enforce the code. Even if there is no building inspector, it would still pay to follow the code as closely as possible to avoid possible trouble with banks and insurance companies.

Whether the code will be a help or a hindrance depends on where you are located. For example, California and Massachusetts have recently adopted state codes which were written in the "bigger is better" era. Both of these codes make life difficult for those who wish to build small houses or do construction themselves. Remember, though, that these states require the local community to enforce the

code. Careful selection of your homesite may enable you to avoid quite a few hassles. On the other hand, many new and sensible codes are "in the works" because of the energy crisis. The federal government is considering minimum insulation standards on a national basis. How it plans to enforce these standards is still unknown. In any case, it will pay to insulate as heavily as possible, so don't be afraid of any restrictions such as these.

For those would-be builders who do have to face the reality of codes, there is some advice on how to deal with them. First, obtain a copy of the code which has been adopted for your area. Also, find out who is responsible for the enforcement of the code. Most towns have one or more building inspectors who issue building permits and then follow up with field inspections to see that the construction conforms to the code. After obtaining the code, read it thoroughly. It will pay to get a copy of the code before committing yourself to the purchase of a piece of property. Refer carefully to the checklist at Figure 1.2 to see if there are any provisions which you can't meet. It is possible for someone to sell you a piece of property on which you can't legally build! Also, study carefully the beginning sections of the code book concerning jurisdiction, enforcement, and appeals. After this, you are ready to consider building your home.

FIGURE 1.2
BUILDING CODE CHECKLIST

ITEM	CODE REQUIREMENTS		CAN YOU MEET IT?	
	YES	NO	YES	NO
1. Minimum area of lot (lot size)				
2. Number of families permitted				
3. Minimum or maximum house area				
4. Building height and set-back restrictions				
5. Foundation type (Is masonry required?)				
6. Is post and beam framing permitted?				
7. Is grade stamped lumber required for framing (i.e., new and klin dried)?				
8. Minimum room sizes				
9. Minimum door sizes and number of exists				
10. Window sizes and ventilation requirements				
11. Forced ventilation for kitchen and baths				
12. Fire retardant enclosure for exitways				
13. Fire alarm system				
14. Riser and tread sizes for stairs				
15. Minimum insulation requirements				
16. Chimney clearances (Is prefab allowed?)				
17. Can owner finish a shell by contractor?				
18. Can attic or some rooms be left unfinished?				

The above list is by no means comprehensive. It is intended to call to your attention the most likely code restrictions that might adversely affect your construction of a house or remodeling of an existing building.

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MODULE #8

BUILDING CONSTRUCTION VERSUS ENERGY CONSUMPTION

UNIT 2

BUILDING SITE AND DESIGN

OBJECTIVES: Upon completion of this unit the student will be able to:

1. Recognize the significance in building orientation.

2. Discuss the significance of designing houses to utilize wall and glass area to control heat loss and heat gain.

3. Discuss the relationship between floor area and percentage of glazed area.

4. Compute annual estimated heating and cooling cost savings for installing energy conservation measures, such as storm doors and windows.

5. Explain the meanings of K factor, U factor, and R factor, and to compute each for certain building materials.

6. Distinguish between various types of insulation material.

7. Recognize the significance in heat loss in wall, ceiling, and glazed areas, and to insulate for better efficiency.

8. Discuss the advantages of shading devices for saving energy.

9. Discuss the effects of building mass on energy conservation.

LECTURE

LABORATORY

A. ORIENTATION

When a builder decides to investigate the possibility of building in a particular location there are several things which he takes into account in his consideration of the site. Among these are accessibility to roads and utilities, proximity to schools, churches, shopping centers, topographic features, drainage patterns and other factors which will influence his development of the site. Having decided the development is feasible and that a market exists for the dwellings that he can build on the land, he should now proceed one step further and consider how best to design and site the dwellings to enhance energy conservation.

Refer to page 2 of Unit 4 to follow along with this topic of lecture.

The first thing that the builder should consider is the type of house he intends to build. Should be build a onestory or two-story dwelling or a combination? What shape should it be? At first glance it would appear that a two-story dwelling would have less heat loss than a one-story dwelling of the same square feet of floor space. This can be illustrated by taking the dimensions of a house and computing the total area of the exterior walls and ceiling where insulation is required, and then comparing it to the same house converted to a one-story dwelling.

a. Two-story
36' wide; 24' deep; 15'9" high
Walls
36' x 15.75' x 2 = 1134 ft^2
24' x 15.75' x 2 = 756 ft^2
1890 ft^2

Ceiling
36' x 24' = 864 ft^2
2754 ft^2

b. One-story Rectangular - Short
36' wide; 48' deep; 7' 6 1/2" high
Walls
36' x 7.54' x 2 = 543 ft^2
48' x 7.54' x 2 = 724 ft^2
1267 ft^2

Ceiling
36' x 48' = 1728 ft^2

Total 2995 ft^2

c. One-story Rectangular - Long
72' wide; 24' deep; 7' 6 1/2" high
Walls
72' x 7.54' x 2 = 1086 ft^2
24' x 7.54' x 2 = 362 ft^2
1448 ft^2

Ceiling
72' x 24' = 1728 ft^2

Total 3176 ft^2

The total area of walls and ceiling in the two-story dwelling is less than one-story dwellings of same floor area. This would give the impression that there is less heat loss in the two-story house. If we examine the figures more closely we will note that the total wall area of (a) is 1890 ft^2, that of (b) is 1267 ft^2 and (c's) wall area is 1448 ft^2. This data is significant for several reasons. First, we must consider the insulating capability of the structure. The typical maximum full thickness insulation used in 2' X 4' walls is R-11 which limits the heat loss reduction per square foot to a fixed amount. Much thicker insulation can be used in ceilings, which means that ceilings have a potential for greater heat loss reduction. Thus, the one-story houses with the larger ceiling area, 1728 sq. ft., to which the greater amounts of insulation can be applied, can have less heat loss (at lower insulation costs) than a two-story house which has the greater wall area. Of the two one-story houses, the

rectangular house with least wall area can be expected to have less heat loss all things being equal. This alone tends to offset, to some degree, the fact that the two-story dwelling has less total area of walls and ceilings.

The second and more important factor we must look at is the amount of glazed area in the structure, since the greatest percentage of heat loss and gain is usually through infiltration which typically occurs around window and door openings. Most codes require a minimum glazed area of 10% of the floor area.

During the planning phase, attention must be given to the orientation of the house as well as to its design. In order to achieve proper building orientation, many factors must be taken into account. The topography, noise reduction, scenic views, concern for privacy, and the climatic factors of wind and solar radiation are all important and have a direct bearing on the livability of housing.

The most complicated and often ignored factor affecting orientation is solar radiation. There are many variables to take into account. The wind, seasonal changes, and regional climatic differences in the United States make this a difficult subject to talk about. For example, in northern latitudes where the air is generaly cool, there is a need to orient the building toward the sun, but in southern regions the axis of the building should be turned to avoid direct solar radiation and oriented toward cooling breezes instead. In the more temperate zones where winter heating and summer cooling are both important, a dual role is required of the structure and orientation often becomes a more difficult and critical factor to consider.

Generally, for best living conditions (warmth in winter, coolness in summer) principal facades of buildings should face south. In cool regions the optimum orientation (i.e. the direction the long side of the house should face) lies 12°E of south, in hot humid regions 50°E of south is desirable, in hot arid regions direct southern exposure to 35°E of south is acceptable; and in temperate regions 17 1/2°E of south achieves a balanced heat distribution. The most troublesome orientation is toward the west. Walls facing into the direct summer afternoon sun absorb radiant heat at a time when the house may have already become overheated due to radiant heat from the sun and warm air outside. During the winter, the prevailing cold winter winds impinge on west walls in many locations. The chart in Figure 2.1 offers suggested sun orientation for residential rooms.

FIGURE 2.1

SUGGESTED SUN ORIENTATION

	N	NE	E	SE	S	SW	W	NW
Bedrooms	x	x	x	x	x	x		
Living				x	x	x	x	
Dining			x	x	x	x	x	
Kitchen			x	x	x	x		
Library	x	x						x
Laundry	x	x						x
Play				x	x	x	x	
Drying yd.				x	x	x	x	
Bathrooms	x	x	x	x	x	x	x	x
Utility	x	x						x
Garage	x	x	x	x	x	x	x	x
Workshop	x	x						x
Terraces			x	x	x	x	x	
Sun Porch				x	x	x	x	

B. GLAZING

The amount of glazed area is important as far as energy conservation is concerned. In fact, windows and doors, with their associated air infiltration loads, are components as important to heating and cooling requirements as is insulation of wall and ceiling areas.

Most codes require a minimum glazed area of 10 percent of the floor area. The window area of most dwellings is normally about 15 percent of the floor area. A single-pane window, with a typical U factor of 1.13, has a heat loss that is more than ten times greater than a residential wall or ceiling having a typical U factor of 0.10. Double-pane windows (also called insulated glass or thermopane) have a U factor that is about 0.50, which is less than half as much as a single-pane window.

Adding storm windows over the single-pane windows of your home can also reduce heat loss by 40-60%. Adding storm doors to existing door frames can have a similar effect. Window awnings may also be used to advantage in sunny exposures to reduce radiated heat passing through the window by about 15%.

When reducing window areas, it is recommended that it be done by raising the sill height. By doing so the upper portion of the window, which provides better natural illumination, remains in place. This also helps reduce heat gain in the summer because the upper portion of the window is more easily shaded by overhang. Using light color finish for walls, ceilings, and floors will enhance the level of natural light.

Turn to pages 7 and 8 in Unit 4 to follow the lecture with laboratory material.

The decision whether or not to install storm windows and storm doors is one largely based on economic feasibility. Will the amount of energy savings be worth the extra cost? This can be determined by calculating the annual estimated heating and cooling cost savings.

$$\text{Est. Annual Heating Cost} = \frac{\text{Heat Loss} \times HI \times 24}{\Delta t \times 100{,}000}$$

$$= \$/\text{year}$$

$$\text{Est. Annual Cooling Cost} = \frac{\text{Heat Gain} \times CI}{100{,}000}$$

$$= \$/\text{year}$$

HI=Heating Index factor which combines heating degree days, cost of fuel and average efficiency of heating system.

CI=Cooling Index which combines operating hours per season, cost of fuel or electricity for cooling and system efficiency.

Δt=temperature difference between 70°F inside and winter design temperature.

Besides relating to heat loss in the winter, the design of glazing can also have a considerable impact on the cooling load of the house in the summer. The area, location, and shading of windows and the use of double glazing or storm sash are important energy conservation factors for air conditioning.

C. INSULATION

There is no simple answer to the question of how much insulation should be used. The optimum amount of insulation depends on a number of factors which vary from city-to-city, such as severity of heating or cooling season, first costs of installing insulation, fuel and energy rates, etc. However, the most important factor to consider when determining the amount of insulation to install is the total design heat loss or heat loss per square foot that is to be achieved.

Another important factor to consider when deciding how much insulation to use is the first cost involved compared to the amount of savings that will result in operating costs over the life of the house.

Workmanship is important also. The manner in which insulation is installed can have as great an effect on heat loss or gain as the insulation itself.

In order to understand insulation you must be familiar with the terminology of heat transfer. The conducting or insulating properties of different materials are rated using three factors. Actually, all three factors give you essentially the same information, but they are used in slightly different ways. The proper understanding and use of these factors can help you in selecting everything from basic building materials to complete walls, ceiling, and floors. The heat transfer factors are represented by the letters K, U, and R. You will see at least one of these letters appearing in a variety of tables and charts that list the insulating properties of either basic building materials or standard structures already containing various types of insulation.

Turn to pages 10 through 15 of Unit 4 for laboratory material.

For convenience in comparing and working with these factors, they are all based on a one-square-foot section of the material and on a one-degree temperature difference between surfaces. The thickness of the material may vary, but it is always listed in the table with the heat transfer value.

1) The K Factor

The K factor is a conduction factor that tells you how much heat energy will pass through a piece of insulating material. The K factor is given in BTU per hour for one square foot of surface area and a temperature difference between surfaces of one degree. All heating and cooling loads, furnaces, and air conditioners are rated in BTU per hour, so the K factor gives you information that is immediately usable.

Figure 2.2 gives some K factors for common materials. For example, the K factor for a one-inch-thick piece of cork board is 0.27. This means that a piece of cork measuring one foot by one foot will allow 0.27 BTU per hour to pass through if the temperature difference is one degree. Doubling either the temperature difference or the surface area will double the heat conduction, but doubling the thickness of the material will cut the heat conduction in half. In other words, you can use K factors for any thickness material covering any size area and for any temperature difference. All you have to do is multiply the K factor by the actual temperature difference and by the surface area, while you divide the K factor by the proportionate increase in

FIGURE 2.2

K FACTORS FOR COMMON BUILDING MATERIALS

MATERIAL	THICKNESS	K FACTOR
CORK BOARD	1"	0.27
FIBERGLASS	1"	0.27
GLASS FOAM	1"	0.40
POLYSTYRENE FOAM	1"	0.15
ROCK WOOL	1"	0.29
FIR	1"	0.67
PINE, SOFT	1"	0.86
PARTICLE BOARD	1"	0.50
SAWDUST	1"	0.41
BRICK, FACE	1"	10.00
BRICK, COMMON	1"	5.00
GYPSUM WALL BOARD	1"	0.70
STONE	8"	0.70
STONE	12"	0.50
CINDER BLOCK	8"	0.50
	12"	0.35
CONCRETE, BLOCK	8"	0.55
	12"	0.45
CONCRETE POURED	8"	0.70
	12"	0.50

thickness. For example, if you are tiling an 8 ft. by 12 ft. wall with cork board that is 2 in. thick, and the temperature difference is 10 degrees, the heat conduction would be:

$$\frac{(\text{K factor}) \times (\text{width}) \times (\text{length}) \times (\text{temperature difference})}{(\text{increase in thickness})}$$

$$= \frac{0.27 \times 12 \times 8 \times 10}{2} = 129.6 \text{ BTU per hour}$$

Be careful when using any of these heat transfer factors that you carefully note the thickness of the material given in the table. Often the thickness is given for standard product sizes, as for concrete blocks. But in other cases the thickness is for just one inch. If you use, say, 6 inches of fiberglass and the K factor was for 1 inch, you would divide by 6 since you were using 6 times as much insulation. But if you use 6 inches of poured concrete when the K factor given is for, say, 8 inches, then you would have to divide by 6/8, or 3/4, since you were using only 3/4 as much material.

All building materials -- fir, pine, brick, concrete, foam insulation, etc. -- have their own K factors. Materials that conduct heat more rapidly have higher K factors than materials that insulate well. So when comparing K factors, the lower the K factor the better.

2) The U Factor

The U factor is a universal factor because it applies to wall construction rather than to specific materials. If you knew how the wall in a home was constructed, you could use the various K factors for each material to find out what the heat conduction would be through the wall. But this approach would be rather tedious, and it might not be very accurate either. If available, the U factor is the one to use because it often takes into account the effect of wind speed and surface finishes on each side of the wall. For our purposes, we will ignore such details as finishes, air films, and wind speeds, since they have only a minor effect on the final heat conduction value.

Like the K factor, the U factor is also expressed in BTU per hour for a one-square-foot area of wall and a one-degree temperature difference. Knowing the U factor of a wall allows you to figure out what amount of heat is escaping. You can then compare the U factors of different wall constructions to determine what type of construction has the lowest heat conduction and, therefore, the best insulation properties. Knowing the U factor also helps in quickly determining the heat load of a home, since the same BTU energy units are used in calculating heat loads.

Heating contractors and utility companies use charts and tables for estimating heat loads that are based on typical constructions and home designs in their location. These charts already include the winter design temperatures in your area, so it is only necessary to know the general size and home style (ranch, bungalow, etc.) in order to estimate your heating requirements to a fair degree of accuracy. But if such detailed charts are not readily available, or if your home differs greatly from the typical homes listed, then the heat load can be determined by multiplying the U factor of each wall by the area of the wall and by the temperature difference.

To find the U factor of a wall from the K factors of each material in the wall, use the following formula:

$$U = \frac{1}{\frac{\text{thickness of A}}{\text{K factor of A}} + \frac{\text{thickness of B}}{\text{K factor of B}} + \frac{\text{thickness of C}}{\text{K factor of C}}}$$

where A, B, and C are the materials in the wall.

It is easy to see that this would be a fairly cumbersome method of figuring the heat loss through a wall. For this reason, the charts and tables for complete walls are much more desirable to work with. Such charts can tell you at a glance what effect added insulation can have on your home, whether it is already built or still in blueprint form. You will also be able to see what effects different sidings and insulation materials have, as when adding aluminum siding over an existing lap or shingle siding. (Aluminum siding, by the way, also comes with insulation on the underside.) The U and K factors can be of great help when designing a new home, permitting you to select materials that can prevent a lot of heat loss.

3) The R Factor

The R factor is a <u>resistance</u> factor that tells you how much a given material resists the flow of heat through it. The R factors given in Figure 2.3 show typical values for common building materials.

FIGURE 2.3

Resistance Values of Structural and Finish Materials, Insulations, Air Spaces, and Surface Films*

Wood bevel siding, 1/2 x 8, lapped	R-0.81
Wood siding shingles, 16", 7½" exposure	R-0.87
Asbestos cement shingles	R-0.03
Stucco, per inch	R-0.20
Building paper	R-0.06
1/2" nail-base insul. board sheathing	R-1.14
1/2" insul. board sheathing, regular density	R-1.32
25/32" insul. board sheathing, regular density	R-2.04
1/4" plywood	R-0.31
3/8" plywood	R-0.47
1/2" plywood	R-0.62
5/8" plywood	R-0.78
1/4" hardboard	R-0.18
Softwood, per inch	R-1.25
Softwood board, 3/4" thick	R-0.94
Concrete blocks, three oval cores	
Cinder aggregate, 4" thick	R-1.11
Cinder aggregate, 12" thick	R-1.89
Cinder aggregate, 8" thick	R-1.72
Sand and gravel aggregate, 8" thick	R-1.11
Lightweight aggregate (expanded clay, shale, slag, pumice, etc.), 8" thick	R-2.00
Concrete blocks, two rectangular cores	
Sand and gravel aggregate, 8" thick	R-1.04
Lightweight aggregate, 8" thick	R-2.18
Common brick, per inch	R-0.20
Face brick, per inch	R-0.11
Sand and gravel concrete, per inch	R-0.08
Sand and gravel concrete, 8 inches thick	R-0.64
1/2" gypsumboard	R-0.45
5/8" gypsumboard	R-0.56
1/2" lightweight-aggregate gypsum plaster	R-0.32
25/32" hardwood finish flooring	R-0.68
Asphalt, linoleum, vinyl, or rubber floor tile	R-0.05
Carpet and fibrous pad	R-2.08
Carpet and foam rubber pad	R-1.23
Asphalt roof shingles	R-0.44
Wood roof shingles	R-0.94
3/8" built-up roof	R-0.33
Glass	
Single glass (winter)	U = 1.13
Single glass (summer)	U = 1.06
Insulating glass (double)	
1/4" air space (winter)	U = 0.65
1/4" air space (summer)	U = 0.61
1/2" air space (winter)	U = 0.58
1/2" air space (summer)	U = 0.56
Storm windows	
1" to 4" air space (winter)	U = 0.56
1" to 4" air space (summer)	U = 0.54
Insulation	
2" – 2½" thick	R-7.00
3" – 4" thick	R-11.00
5" – 7" thick	R-19.00

Air Spaces (3/4")	
Heat flow UP	
Non-reflective	R-0.87
Reflective, one surface	R-2.23
Heat flow DOWN	
Non-reflective	R-1.02
Reflective, one surface	R-3.53
Heat flow HORIZONTAL	
Non-reflective (also same for 4" thickness)	R-1.01
Reflective, one surface	R-3.48
Note: The addition of a second reflective surface facing the first reflective surface increases thermal resistance values of an air space only 4 to 7 per cent.	
Surface Air Films	
INSIDE (still air)	
Heat flow UP (through horizontal surface)	
Non-reflective	R-0.61
Reflective	R-1.32
Heat flow DOWN (through horizontal surface)	
Non-reflective	R-0.92
Reflective	R-4.55
Heat flow HORIZONTAL (through vertical surface)	
Non-reflective	R-0.68
OUTSIDE	
Heat flow any direction, surface any position	
15 mph wind (winter)	R-0.17
7.5 mph wind (summer)	R-0.25

Example calculations
(to determine the U value of an exterior wall)

Wall Construction	Uninsulated Wall Resistance	Insulated Wall Resistance
Outside surface (film), 15 mph wind	0.17	0.17
Wood bevel siding, lapped	0.81	0.81
½" ins. bd. sheathing, reg. density	1.32	1.32
3½" air space	1.01	
R-11 insulation		11.00
½" gypsumboard	0.45	0.45
Inside surface (film)	0.68	0.68
Totals	4.44	14.43

For uninsulated wall, $U = \frac{1}{R} = \frac{1}{4.44} = U = 0.22$

Therefore, heat loss for the above uninsulated wall section at a +10° F. outside design temperature is equal to 0.22 x 60 (or 70-10) equals 13.2 Btuh per sq. ft. of wall section.

For insulated wall, $U = \frac{1}{R} = \frac{1}{14.43} = U = 0.07$

Therefore, heat loss for the above insulated wall section at a + 10° F. outside design temperature is equal to 0.07 x 60 (or 70-10) equals 4.2 Btuh per sq. ft. of wall section.

* Additional resistance values can be obtained from ASHRAE Handbook of Fundamentals published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

The R factor differs from the K and U factors in that a large R factor is better than a small one. In other words, the larger the R factor, the better the material resists the flow of heat. Most insulation materials have R factors printed on them. If you look closely at a roll of fiberglass insulation, you'll see an R number printed on it. For example, a roll of four-inch-thick fiberglass might have the number R-11 printed on it, which indicates that its R factor is 11. Building specifications will often list an R

number for the insulation and leave it up to the contractor to meet the requirements with the most economical materials available. For example, in the far northern states, it is presently recommended that you use R-30 ceiling insulation and R-19 insulation in floors.

The R factor is just the reciprocal of the U factor; that is, R=1/U and U=1/R. The wall in the previous example had a U factor of 0.65, which is equivalent to an R factor of 1/0.65, or 1.54. So the R factor of the wall was 1.54. Reversing the calculations, if you knew the R factor of the wall, you could find the U factor, since U=1/R.

The R factor is the principle factor used to rate the effectiveness of insulation, and most materials have an R factor printed on them. But most building materials such as wood, brick, siding, etc. are usually rated in K and U factors, although it is simple to convert them to R factors. Heating contractors and most fuel companies normally use U factors to figure the heat load of a house, while electric power companies seem to favor using R factors (probably because of the similarity to electrical resistance).

The most important use of the R factor is as an aid to the homeowner in determining the resistance of the various types of insulation. With the R values, you can compare the insulating qualities and costs to decide which type is best for your particular use.

4) Types of Insulation

There are several features that you'll want to compare as you look over the insulators that are commercially available: cost, resistance factor per inch of thickness, fire rating, and durability. Before we examine the various qualities that different insulators have, let's look at the forms of insulation that are available:

Blankets. Blankets come in rolls, usually from 16 to 24 inches wide, and are unwound and cut to fit in place between wall studs or ceiling and floor joists.

Batts. Batts are similar in size to blankets but are precut to specified lengths.

Boards. Boards are precut to standard sizes and are usually applied with a mastic as perimeter insulation around the foundation or over existing walls for renovation work.

Loose-Fill. This type of insulation comes as a loose granular material in bags and can be poured into place between joists or behind walls.

Blown Insulation. This is a spray-foam style of insulation which is installed under pressure behind walls and between joints in ceilings and floors by professionals.

Now, let's look at the qualities that the various commercial insulators have:

Fiberglass. Fiberglass is perhaps the most common of all insulators today; it is available in rolls or batts. The resistance of fiberglass is about 3.5 per inch of thickness. Fiberglass is fire and vermin proof, moderate in cost, and easy to install. However, over some years it will tend to mat down or settle on itself. The result is that the material is compressed a bit and loses some of its insulation value.

Mineral Wool. Mineral wool is much like fiberglass, except that the material is made from melted rock instead of glass. The resistance value is a bit less than fiberglass--about 3 per inch--and the problems with matting are even worse.

Insulating Sheathing. This is a material made from wood fibers and is usually applied on exterior walls as a backing for siding. It comes in various thicknesses, usually between 1/2 and 1 inch. The resistance is about 2 per inch of thickness; and though it's water repellent, extended exposure to moisture will cause damage through mildew and rot.

Plastic Insulation. The most common type of plastic insulation is polystyrene, which comes either as a blue "closed-cell" foam board or as white granule boards where the granules have been heated and pressure treated so they adhere together. The resistance of these materials is about 5.5 for the blue closed-cell type and 4 for the white granule type. Polyurethane, on the other hand, comes as closed-cell foam boards or can be professionally blown into place inside walls, ceilings, or floors as a foam. In either case, its resistance value is about 6.5 per inch.

Polystyrene and polyurethane tend to be expensive. Moreover, while both are good insulators and do not attract moisture or vermin, there are extreme fire hazards involved. Both will burn very rapidly and give off toxic gases, particularly when placed in a vertical position. These materials should therefore never be installed where they will be exposed. The best applications are for perimeter insulation on the outside of foundation walls.

Loose-Granule Mineral-Based Insulators. The most common of these insulators are vermiculite and perlite, available as loose-fill insulation at moderate costs. The resistance is about 2.5 per inch. These materials are fire-proof and will not deteriorate from moisture, rot, or insect problems. However, settling out can be a problem, particularly when they are placed in a vertical position between wall studs.

Cellulose Fiber. These fibers are often made from recycled paper that has been chemically treated to resist fire, rot, and vermin. In addition, this kind of insulation has good sound-deadening properties. It comes as a loose-fill insulation, though this variety has the settling out problems of the fiberglass, mineral wool, or loose-granule mineral-based insulators.

D. WALLS

Adding insulation to a wall will increase its R value or decrease its U value. In either case, the amount of heat escaping through the wall will be reduced. Adding one inch of insulation to an uninsulated wall will reduce the heat loss through the wall by 40-50%. Adding two inches of insulation will reduce the heat loss by 60-65%. Adding three inches

will cut heat loss by 70-75%, and adding four inches will cut heat loss by 75-80%. All of these quoted percentages depend on the particular type of insulation used and on the construction of the wall before insulation is installed, but they represent typical figures.

As you can see, adding more and more insulation has less and less effect on the percentage decrease in heat loss through the wall. For most applications, there is little benefit to be gained by adding more than four inches, since the added cost generally outweighs the benefits received in fuel savings. The best approach is to use better insulation rather than thicker insulation.

The temperature difference between the inside and outside of your home is the main factor in determining how much insulation should be used in the walls, ceilings, and floors. If you live in the northern part of the U.S., where cold winters are the rule, you will spend more money in obtaining more and better insulation than if you lived in the south. In some regions of the country, the cost of fuel is especially high, and this too dictates the use of more insulation. Aside from the heating aspect of your home, there is also the cooling side, which would also benefit from added insulation. So, in the southern states insulation can reduce the cost of air conditioning your home more than it would reduce the cost of heating it.

The addition of insulation to the walls, ceilings, and floors of a home reduces heat transfer -- convection, conduction, and radiation. Air is actually a very poor conductor of heat, even though it is able to transfer large amounts of heat energy by convection. The

trick is to prevent the air from moving or circulating and this is the way most foam, spun, or batting insulation materials work. Some insulation, such as plastic foam and closed-cell insulation, actually creates dead air pockets by holding the air in sealed bubbles. Other insulation, such as batting and spun fibers, merely prevents the air from circulating freely. In either case, the motion of the air is drastically reduced and only a small amount of heat is transferred by conduction through the air.

Good insulation has a high R factor and a high resistance to the conduction of heat through the wall. Even though convection may be a significant factor of heat transfer within the wall cavity, the insulation properties of the wall itself are treated as a conduction effect. Therefore, the addition of insulation with the wall acts to lower the conduction of heat through the wall. The more insulation that is added to the wall, the higher the R value and the resistance to heat flow.

Even some of the best insulating materials can become rather poor insulators if they are allowed to get wet. The problem with moist air is that it can condense and saturate some insulations, permitting the water, which has a very high heat conductivity, to transfer heat energy through the wall. Even worse, the presence of water or high amounts of moist air can rot and warp wooden beams and paneling. In particularly moist locations such as basements or other masonry walls, the best vapor barriers is obtained by using large sheets of plastic installed directly against the masonry wall. Large rolls of heavy gauge plastic are available from most building material suppliers for just this

purpose, and the rolls are wide enough to extend from floor to ceiling and from wall to wall. Since concrete and cement-block walls are fairly poor insulators, it is a good idea to use at least some insulation behind the paneling in basements.

E. CEILINGS

Insulating the ceiling is very important in a house. As much as 75% of the heat loss in a house goes right through the ceiling in the winter, so obviously it is important that this part of your home be well insulated. Insulation in the ceiling will hold in the heat, which has a tendency to rise and escape through the ceiling into the attic space. In the summer, the heat flow reverses and extremely hot temperatures in the attic warm the rooms in the living area below.

For most applications, six to ten inches of insulation in the ceiling is needed to prevent excessive heat gain or loss through the ceiling. Again, this will depend on your area, the winter and summer design temperatures, and other factors. You should contact a local builder or insulation company to get recommendations. More than 10 inches of insulation (R-30) usually costs more than the extra insulation is worth, but this varies. Twelve inches of insulation (R-38) is justified in some northern states where fuel costs are especially high. There are several different ways that the ceiling can be insulated, including blown-in insulation, fiberglass batting insulation, or a combination of insulation types.

Turn to pages 5 and 6 of Unit 4 for laboratory material.

There are other ways to reduce the energy loss through the ceiling besides insulation, although this is the most important. One way to reduce heat gain in the summer is to lower the temperature of the attic above the living area of the house. When the attic is cooler, less heat will be transferred into the rooms below, and the air conditioner will have less of a load. The temperatures in attics can often exceed 125°F, and this adds a considerable amount of heat to the living space.

You can lower the temperature of the attic by installing an automatic fan and vents. Just installing vents at each end of the attic will often allow enough air circulation to lower the temperature of the attic quite a bit. Forcing the ventilation with a fan can lower the attic temperature even more. A section discussing attic fans and giving installation tips appears in a later chapter.

The color of the roof has an effect on the amount of heat gain in the house. An important thing to remember here is that heat gain is undesirable in the summer, but it is desirable in the winter. This presents somewhat of a dilemma for the homeowner. While a dark-colored roof will absorb sunlight and add some desirable heat to the attic in the winter, this same dark roof will add heat to the attic in the summer when it is undesirable. A light-colored roof will help reflect the sun's rays and leave the attic somewhat cooler than a dark roof in the summer. From the standpoint of energy conservation, we would recommend a light-colored roof because most homes stand to benefit more from a lighter roof in the summer than they would from a dark roof in the winter. This is purely an energy-saving suggestion, however, since design or style will probably have more to do with the color and type of roof selected for a home than matters of energy conservation.

F. SHADING DEVICES

Sun control through shading devices is an important factor in considering heat gain. There are many ways to shade a structure. One of the most effective methods is the use of deciduous trees planted adjacent to a south window wall. The foliage screens out the summer sun and the bare branch structure allows the sun heat to reach the house during the winter season.

The homebuilder does not always have the luxury of a heavily wooded site and must utilize architectural methods in order to provide adequate shading. The most common method is roof overhang. A properly designed overhang on the south wall will protect the wall from summer sun and expose the wall to the winter sun.

The sun's arc is low in the winter and high in the summer. The south wall of the house should therefore have an overhang projection which shades the wall from the high summer sun but permits the sun to warm the south wall during the winter months.

There are other examples of shading and screening devices which can also offer aesthetic value as well as energy conservation value. Such methods include the wooden trellis, louvered overhangs, canvas awnings and panels, horizontal and vertical louvered panels, adjustable shutters for windows and doors, and masonry grills.

G. EFFECTS OF BUILDING MASS ON ENERGY CONSUMPTION

All other things being equal including color and "U" value, buildings employing heavy weight walls and roof exhibit beneficial characteristics with regard to energy, particularly for air conditioning.

When the sun shines through a window, its heat gain to the space is almost always instantaneous. Similarly, when the sun shines on light weight walls, the energy that it imparts to the wall is transmitted into the room in a short period of time. Obviously, the air conditioning equipment must have the capacity to remove this heat at the time that it enters the room or shortly thereafter.

When heavy weight construction is used, it takes time for the sun's energy to go through the heavy weight material. This time can range from a few hours up to as much as half a day. The peak heat gain into the space is therefore delayed by several hours and generally tends to be smoothed out over several hours, so that both the capacity of the air conditioning equipment can be reduced and the amount of energy required is reduced. The energy reduction is due to the fact that: (1) air conditioning equipment operates more efficiently at night because the outside temperatures are usually lower, and (2) as the outside temperature drops at night, some of the heat that has been stored in the wall can reverse its flow and therefore never enter the space at all.

MODULE #8

BUILDING CONSTRUCTION VERSUS ENERGY CONSUMPTION

UNIT 3

WEATHERIZATION

OBJECTIVES: Upon completion of this unit the student will be able to:

1. Discuss weatherization practices available to the homewowner for more efficient doors.

2. Discuss weatherization practices available to the homeowner for more efficient windows.

3. Identify various types of caulking compounds and their life expectancy.

4. Discuss the advantages of caulking for saving energy.

5. Identify and discuss conservation practices in the home during the heating season.

6. Identify and discuss conservation practices in the home during the cooling season.

LECTURE

One of the most important ways that energy can be conserved in the home is by weatherization. Through weatherization more heat is kept inside the house during the winter months and out during the summer months. Some of the most important factors that should be considered in the process of weatherization are as follows:

LABORATORY

The information gathered in Unit 4 should be discussed with this unit to learn of weatherization measures one can take to increase energy efficiency in the home.

A. Doors

Doors should be located away from prevailing winds in cold climates and facing into the wind in warm climates.

Even though you may be an inexperienced handyman, you can weatherstrip your doors with little difficulty. There are several different types of weatherstripping that may be used for doors. These include adhesive backed foam, rolled vinyl with aluminum channel backing, foam rubber with wood backing, and spring metal.

While the adhesive backed foam is very easy to install and invisible when it is installed properly, it is not very durable. It is more effective on doors than on windows. The only tools needed for its installation are a knife or shears and a tape measure. For installation, simply measure the amount needed, stick the foam to the inside face of the jamb and press in place.

The rolled vinyl with aluminum channel backing is visible when installed but is easy to install and very durable. To install, measure and cut the amount of stripping necessary and nail the strip snugly against the door casing.

While the foam rubber with wood backing may be used in stripping doors, it is not very durable and it is visible when installed. To install, measure the amount needed, cut and nail the strip against the door casing. Space the nails about eight inches apart.

Another material mentioned above that might be used for weatherstripping doors is spring metal. Besides being easy to install and invisible when installed properly, it is also very durable. Measure

the amount needed, cut with tin snips to the proper length and nail in place. For a better seal, lift the outer edge of the strip with a screwdriver after tacking.

Door shoes are good for stripping the bottom of doors. They are useful with wooden thresholds that are not worn. Door shoes are very durable, but very difficult to install. The door must be removed and the required amount trimmed off the bottom edge. Cut the shoe to the door width. Install by sliding the vinyl out and fastening the shoe to the bottom of the door with screws. (To do this job, you will need a screwdriver, hack saw, plane and a tape measure.)

A vinyl bulb threshold is another possibility that you might consider for weatherproofing the bottom of your doors. The vinyl bulb threshold is especially useful when there is no threshold or when the wooden one is worn out. It is difficult to install and the vinyl will wear out, but replacements are available. To install this type of threshold, you will need a screwdriver, hack saw, plane and a tape measure. First, remove the door and trim the required amount off the bottom. The bottom should have about 1/8" bevel to seal against the vinyl. Make certain that the bevel is cut in the right direction for opening. The vinyl bulb should seal around the bottom of the door when it is closed.

Another possibility for sealing the air leak under your door is the interlocking threshold. However, it is very difficult to install and should be installed by a skilled carpenter. It does form a very good weather seal.

Interlocking metal channels may also be used in weatherstripping doors. Interlocking metal channels are difficult to install because alignment is critical to achieve a proper seal. This type is also visible when installed and subject to damage. In order to install, cut

and fit strips to the head of the door first. The male strip should go on the door and the female strip on the head and hinge side of the door. A male strip should also go on the jamb. No unusual tools are required to do this job, just a hack saw, hammer and nails, and a tape measure.

Fitted interlocking metal channel is an excellent weather stripping. It forms an exceptionally good weather seal, is invisible when installed and is not exposed to possible damage. It is very difficult to install and should be installed by a carpenter.

Flat thresholds are sometimes weatherized by installing a sweep. However, a sweep may drag on the carpet or rug. Some sweeps are installed on the inside of the door and some on the outside. Check the instructions for your particular kind. Installation is simple. With your hack saw, cut the sweep to fit 1/16 inch in from the edge of the door, then attach to the door with screws.

Consider storm doors. While you may save 10 to 15 percent of the purchase price of combination (windows and screen) storm doors if you install them yourself, you should not attempt such an installation unless you are a relatively skilled handyman. Much trouble and frustration may be saved by hiring a supplier to install them. A combination storm door can be installed by an experienced worker in less than half a day. Before the installer leaves check for the following:

1. The door should open smoothly and fit tight.

2. There should not be wide cracks around the door jamb. The seal should be as air-tight as possible.

3. The exchangeable window and screen panels should fit properly and seal tight.

Storm doors can be purchased that are made of aluminum, steel, or wood. Your choice is primarily a matter of taste. However, there are several factors that should be considered in selecting and judging the quality of a storm door.

1. Finish: Plain aluminum will oxidize. This will reduce the ease of operation of the door as well as detract from its appearance. Therefore, a baked enamel or anodized finish is more desirable.

2. Weatherstripping: Weatherstripping is very important if a storm door is to fulfill its function of reducing air leakage around doors. Therefore, compare the weatherstripping of several different doors.

3. Corner Joints: The corners should be strong and air tight. You should not be able to see through the joints. If you can, they will leak air.

4. Hardware: The locks and hinges have a very direct effect on the durability of the storm door. Also, they are good indicators of the general quality of the door.

B. Windows

Windows should be located in such a manner to receive as much sun as possible in areas of the country where the climate is relatively cool for many months. In tropical climates, however, windows should be positioned in such a manner that they will receive little sun. Thermopane may be relatively expensive, but savings in heat loss may pay for the added cost in a few years by retaining heat or cold, depending upon the requirement.

Weatherstripping a window is similar to weatherstripping a door. (Refer to that section above)

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The simplest method of obtaining good weatherization for your windows is to simply tack sheets of plastic over the outside of your windows. If you prefer, the plastic can be taped over the inside of the window. Whether you install the plastic on the inside or on the outside, be sure that all possible air leaks around the moveable parts of the window are blocked.

Inside installation is more desirable because the plastic is less likely to be damaged. Inside installation is also easier. In either case, the plastic should be stretched tightly. Besides looking better, tightly stretched plastic will be less susceptible to deterioration.

When you are ready to buy the plastic, measure the width of your largest window. Then measure the length of each window you plan to cover in order to determine the number of linear feet of plastic that will be required. The polyethylene plastic sheets (in rolls or kits) should be six mills thick.

If you install the plastic inside, the only tools and materials that you will need will be shears for cutting and trimming the plastic and 2" wide masking tape. Should you install the plastic on the outside, you will require a hammer and tacks and 1/4" X 11/4" wood slats to tack over and around the edge of the plastic in order to keep the tacks from tearing the plastic sheets.

Single pane storm windows are as effective as double-track or triple-track combination windows but they are less expensive. Their main disadvantage is that they can't be opened once they are installed.

If you are a relatively skilled handyman, you can make your own single pane storm windows by purchasing aluminum do-it-yourself materials from any hardware store.

If you prefer, you can measure your windows and then have a storm window supplier build them for you. In either case, it is extremely important that you measure your windows carefully. After you have decided how you want your storm window placed in the window frame, measure around the outside of the window frame where the storm window will sit. For clearance, allow 1/8" along each side of the storm window. Fix the storm windows in place with moveable clips so that they can be removed each summer.

In judging the quality of single pane storm windows there are two important things to look for, the frame finish and weatherstripping. If the finish is plain aluminum, it will oxidize quickly and degrade the appearance somewhat. An anodized or baked enamel finish is preferable. The side of the aluminum frame that touches the window frame should have a permanently installed weather strip of gasket to seal the crack between the window frame and the frame of the storm window. Leave weep holes open at the bottom.

Combination storm windows are more desirable than single pane storm windows because they can be opened anytime.

Triple track combination (windows and screen) storm windows are designed for installation over double hung windows. They are permanently installed and can be opened anytime with a screen slid into place for ventilation.

Double track combination units are also available and they can cost much less. Both kinds are sold almost everywhere and can be bought with or without the cost of installation.

Although you may save approximately 10 to 15 percent of the purchase price of the storm windows if you install them yourself, you should not attempt the installation unless you are a relatively skilled handyman.

While several weeks may be required for the supplier to make up your order, installation is relatively fast. It should not take a skilled workman more than a day to install your combination storm windows. Once the storm windows are installed, be sure that both the window sashes and screen sash move smoothly and seal tightly when closed. Also, make certain that there is a tightly caulked seal around the edge of the storm windows.

The quality of combination storm windows may be reflected in the frame finish, corner joints, sash tracks, and weatherstripping. As we noted earlier, a plain aluminum finish will oxidize and thus reduce the ease of operation. Therefore, a baked enamel finish is better. You should check the corners of the storm windows. They should be strong and air tight. Usually overlapping corner joints are better than mitered joints. Additionally, you should examine the weatherstripping in order to determine its quality. Another factor that is important is the sash track. Deep sash tracks are better in reducing air leaks than shallow tracks.

C. Caulking

Where should you caulk?

Caulking should be done wherever two different materials or parts of a house meet. Specifically a house should be caulked:

a. At joints between window frames and siding.

b. Between window drip caps (tops of windows) and siding.

c. Between window sills and siding.

d. At corners formed by siding.

e. At sill where wood structure meets the foundation.

f. Around outside water faucets, or other special breaks in the outside house surface.

g. Where pipes, wires and ducts penetrate the ceiling below an unheated attic.

h. Between porches and main body of the house.

i. Where chimney or masonry meets siding.

j. Where storm windows meet the window frame, except for drain holes at window sill.

k. If you have a heated attic, where the wall meets the eave at the gable ends.

There are several different types of caulking compounds. Those that have a lead base are not recommended because of the toxic nature of lead. Three types of caulking compounds that can be considered are oil or resin based caulking compounds, latex, butyl or polyvinyl based compounds, or elastomeric caulks. All three types will bond to most surfaces such as masonry, wood, and metal. The elastomeric caulks are the most expensive, but they are also the most durable. Latex, butyl, or polyvinyl based caulks are less expensive and also less durable. The oil or resin based caulks are the least expensive but they are also the least durable.

For filling wide cracks some type of filler such as caulking cotton, oakum, glass fiber strips, or sponge rubber will be required.

If you do the caulking yourself you will need a ladder, a caulking gun, caulking cartridges, some type of filler such as those mentioned above, and a putty knife.

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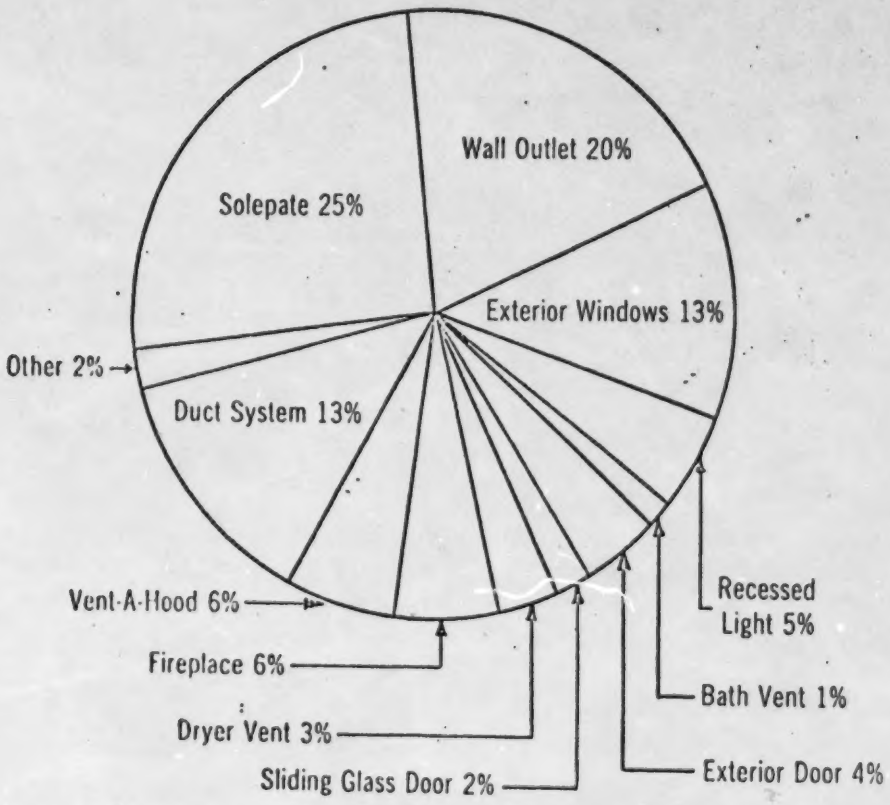
How many caulking compound cartridges will you need? Because of the varying size of cracks that must be filled, it is difficult to estimate. However, about 1/2 of a cartridge is needed for each door or window. Approximately two cartridges are required for a two-story chimney, and four cartridges for the foundation sill.

Air leakage in the home accounts for a great deal of energy loss. For an average family of four living in a home of 1728 sq. ft., Figure 3.1 indicates the seriousness of the problem. Caulking can be the answer to this dilemma.

FIGURE 3.1

AIR LEAKAGE TEST RESULTS FOR AN AVERAGE SIZE HOME OF 1728 SQ. FT.



SOURCE: TEXAS POWER & LIGHT COMPANY

D. ENERGY CONSERVATION MEASURE

The following is a listing of energy conserving practices which the homeowner should use in the operation of his/her home.

1) During the Heating Season

Fireplace damper - Close the fireplace damper when not in use. A typical house will have an air change rate of some 200 cubic feet per minute. When a fireplace damper is left open when not in use, a good deal of hot air escapes up the chimney. This can cause the air to change at an additional 200cfm, truly wasteful and completely unnecessary.

Thermostat setting - Set thermostat back at night. Each 1°F reduction in setting can save approximately 1 percent in fuel. Do not lower the temperature so much that your system must work overly long to reheat or recool your home in the morning. While away from home for an extended period, you should set your thermostat at 55°F. During the daytime close bedroom dampers to reduce the temperature slightly lower than other living areas. Clean thermostats once a year to remove dust.

Humidity Level - High humidity makes our bodies hold heat. Dry air absorbs moisture from the skin at a rapid rate and produces a chilling effect which can only be offset by increasing air temperature. Thus a properly humidified home is as comfortable at 68°F as a dry one at 72°F. In the winter when we want to be warmer, a humidifier may be a wise

investment which will allow us to lower the house temperature *and save energy. A pan of water* strategically located near a heating outlet will help moisturize the air if a humidifier is not available. House plants also help increase humidity by giving off moisture.

Window shades, drapes and blinds - Closed drapes, blinds, and shades over large glass areas can reduce heat lost through windows during the winter. On sunny winter days, however, drapes, blinds and shades should be open to let the sun warm the house. Draperies should be insulated or lined.

Caulking and Weatherstripping - Cracks can form around window and door frames and where wood meets metal or masonry. Air leakage due to these cracks can normally be detected by the presence of cold drafts. A standard exterior door which has a 1/8 inch crack around it loses heat through a total area of 30 square inches. This would be equivalent to having a hole in your wall 5 1/2" by 5 1/2". Keeping weatherstripping and caulking around windows or doors in good repair will help reduce this air leakage.

Storm Windows and Doors - Heat loss through doors and windows can be reduced by more than 50% through the installation of storm doors and windows.

Do not block Radiators or Registers - Obstacles such as furniture, drapes, or pictures in front of heating units or registers can reduce efficiency of the system.

Maintain Heating Equipment-In order to assure maximum operating efficiency of heating plants and minimize fuel input rate to the burner, the following should be done:

Clean heat exchanger surface in the furnace regularly. Dust and products of combustion can deposit on surfaces and interfere with good heat transfer.

Air adjustment should be checked periodically by a service professional. Fuel will not burn completely when there is insufficient air. Heat will be lost up the chimney with too much air.

Air filters should be cleaned or replaced when they become loaded with dust.

An expert should clean and adjust the entire heating system once a year.

Fireplaces - Use of fireplaces as a heating source can be very deceptive. A large flow of air is generated through the hearth and up the chimney by a burning fire. This is usually the air already heated by the furnace, which means that although the fireplace is heating the immediate air, it is cooling the rest of the house by expelling the warm air. This energy loss can be reduced by reducing the thermostat setting and closing doors to the rest of the house while the fireplace is in use.

Hot Water Heater - The hot water heater is the second largest consumer of energy in the home. It should be sized to meet the needs. Maintaining a supply of unwanted hot water wastes energy. Losses in energy

can be decreased by insulating hot water pipes from the source to the point of use. Water should not be overheated. 140°F hot water is the recommended temperature for a house with a dishwasher. When away from home for extended periods, the water heater should be turned down or turned off. If the gas pilot light is turned off, it should be done according to the manufacturer's instructions.

Clothes Drying - Venting of an electric dryer into the house in cold climates conserves heat, but can cause moisture and lint problems. A lint trap should be installed, and the practice discontinued if mnoisture problems occur. Gas dryers must be vented outside the house.

Electricity Use - Avoid using electrical appliances, if possible, between 5 p.m. and 8 p.m. during the winter.

Windbreak Planting - Winter winds increase heat loss from houses. A tall fence or a dense growth of evergreens will reduce wind impact.

2) During the Cooling Season

Shade Planting - Solar heat gain of walls, windows, and roofs can be reduced by planting tall, deciduous shade trees on the east, south, and west sides of the house. In the winter, the leafless trees permit the sun to warm the house.

Thermostat setting - Set the thermostat at the highest setting which is reasonably comfortable. 78°F is the recommended comfortable temperature for most people during the summer. Each degree higher setting can save about 4% of the

air conditioning operation cost. The air conditioner should be turned off while away from home for an extended period.

Dehumidifier - In the summertime a dehumidifier can allow the operation of the air conditioner at a higher temperature, while feeling just as comfortable and saving energy.

Window Shades, Drapes, and Blinds - On sunny summer days light colored drapes, blinds, and shades should be closed on the sunny side of the house to reverse cooling loads. Dark colors absorb heat.

Storm Windows - Storm windows can provide substantial energy savings in the summer as well as in the winter in air conditioned homes. The storm windows form a dead air space which acts as insulation.

Do Not Block Cooling Outlets - Obstacles such as furniture, drapes or pictures in front of cooling outlets can reduce efficiency of the system.

Maintain Cooling Equipment - All air conditioning units have filters which should be cleaned every 30 to 60 days. Equipment manufacturer service manuals usually tell how to best clean the filters. Condenser coils should also be kept clean. In central air conditioning units with the condenser located outside, the finned surfaces of the condenser should be kept free of leaves and mud. It is also a good idea to lubricate the bearings on the blower and electric motor, and to adjust the tension on the fan belt between the motor and blower. If the manufacturer's manual

does not give instructions on these maintenance procedures, a service man should be contacted.

Clothes Drying - In the summertime, it is wise to vent the hot air from a clothes dryer to the outside of the house to reduce moisture and heat in the home.

Electricity Use - Avoid using electrical appliances, if possible, between 1 p.m. and 5 p.m. during the summer.

MODULE #8

BUILDING CONSTRUCTION VERSUS ENERGY CONSUMPTION

UNIT 4

WEATHERIZATION WORKBOOK

OBJECTIVES: Upon completion of this unit the student will be able to:

1. Survey the home and compute for heat loss by infiltration.

2. Survey the home and compute for heat losses by conduction through floors.

3. Survey the home and compute for heat losses by conduction through ceilings.

4. Survey the home and compute for heat losses through single-glass windows.

5. Survey the home and compute for heat losses through double-glass or plastic-covered windows and through doors.

6. Survey the home and compute for heat losses through walls.

7. Calculate cost savings for implementing conservation measures in each of the above area.

LECTURE

The student weatherization workbook is intended for student use in surveying the home and calculating heat gain and heat loss through various features in building construction. It is a culmination of all lecture material covered in this module and is meant as a teaching tool through the above units.

MODULE #8

BUILDING CONSTRUCTION VERSUS ENERGY CONSUMPTION

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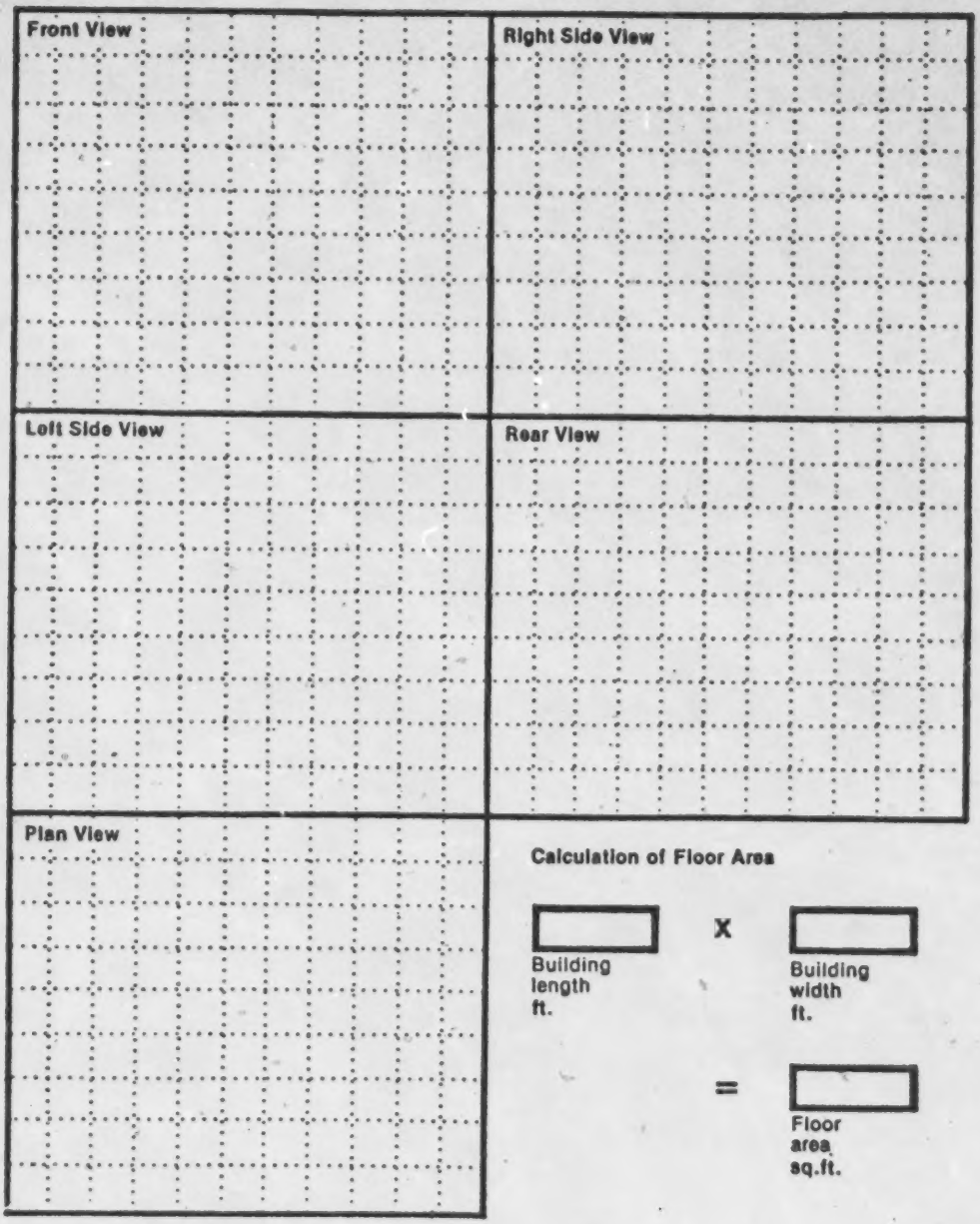
Sketch all views and put dimensions on each part shown, for example, length of walls, width and length of windows, etc. Label all single glass windows S and double glass and doors D . Complete all items in the job book labeled "Fill in at Job Site."

Description of Building



Calculation of Floor Area

[ ] Building length ft. X [ ] Building width ft.

= [ ] Floor area sq.ft.

FILL IN AT JOB SITE

These grids are provided as guides for lines. Drawings need not be done to scale.

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Description of Building

Dwelling Unit Information

Name of Head of Household

_____

Name and Address of Owner:
(if not the same as above)

_____

_____

_____

_____

Occupants of Structure:

☐ Total number

Style of Structure:

☐ One-story

☐ Two-story

☐ 2-1/2 story

☐ Split-level

☐ Other (specify) _____

Age of Structure (approx.):_____ years

Rooms in Living Space:

☐ Total number of rooms

☐ Number used in winter

Occupants Comments (drafty, cold floors, too expensive to heat):

_____

_____

_____

_____

_____

_____

FILL IN AT JOB SITE

Heating System Information

Type of Fuel: (P = Primary) (S = Secondary)

☐ Fuel oil

☐ Bottled gas

☐ Coal/coke

☐ Electricity

☐ Natural gas

☐ Wood

☐ Kerosene

☐ Other (specify) _____

Type of Heating System: (P = Primary) (S = Secondary)

☐ Steam/hot water/hot air

☐ Fireplace/stove/portable heater

☐ Electrical baseboard

☐ Other (specify) _____

Domestic Hot Water:

Does central heating system provide heat for domestic hot water? _____

Thermostat Setting in Winter (average):

_____Day _____Night _____None

Amount of Fuel Used Last Heating Season:

	Primary	Secondary
Type	_____	_____
Quantity	_____	_____
Total Cost	$_____	$_____

District Heating Factor _____
(see page 14)

Heat Loss by Infiltration

On pages 4-9, calculate the heat loss by infiltration and by conduction through the separate parts of the building; enter the results in the table at the bottom of each page and in the summary table on page 10.

House Draft Index: Opposite each of the four component parts of a building in the table below, place a check mark in the circle adjacent to the features which best describe the condition of the building.

Building Component	One Air change per hour (1)	Two Air change per hour (2)	Three Air change per hour (3)
Cellar or Crawl Space	Tight, no cracks, caulked sills, sealed cellar windows, no grade entrance leaks ○ Plywood floor, no trap door leaks, no leaks around water, sewer, and electrical openings	Some foundation cracks, loose cellar windows, grade entrance not tight ○ Tongue-and-groove board floor, reasonable fit on trap doors, around pipes	Major foundation cracks, poor seal around grade entrance ○ Board floor, loose fit around pipes
Windows	Storm windows with good fit ○	No storm windows, good fit on regular windows ○	No storm windows, loose fit on regular windows ○
Doors	Good fit on storm doors ○	Loose storm doors, poor fit on inside door ○	No storm doors, loose fit on inside door ○
Walls	Caulked windows and doors, building paper used under siding ○	Caulking in poor repair, building needs paint ○	No indication of building paper, evident cracks around door and window frame ○

FILL IN AT JOB SITE

Multiply the number of check marks in the first column by 1, the second column by 2, and the third column by 3. The Draft Index will be the sum of these products, divided by 4.

[ ] Floor area sq.ft. x [ ] Height to ceiling (to upstairs ceiling in two-story house) ft. = [ ] Volume of air in building cu.ft.

[ ] Volume of air in building x [ ] Draft index x [ ] District heating factor x.02 = [ ] Heating units required

Potential Savings by Reducing Infiltration

It should be possible to reduce the draft index for a building to 1 (that is, reduce the number of air changes to one per hour). If the draft index for this building were improved to 1, the infiltration loss would be:

[ ] Volume (from above) x [1] Draft index x [ ] District heating factor x.02 = [ ] Potential heating units

Subtract the potential heating units from those now required and enter here →

Type of Heat Loss	Heating Units Required	Potential Heating Savings	Proposed Changes to Structure	Heating Units to be Saved
Infiltration				

Heat Losses by Conduction Through Floors

Floor Exposure Factor
Select the appropriate factor from the descriptions below:

Building on posts or pillars with no skirts below floor	1.0
Crawl space skirted	.8
Rock wall basement	.8
More than 2 feet of basement wall exposed above grade	.8
Building on slab	.5
Building with tight crawl space	.5
Building with tight basement (heated or unheated)	.5

R value of floor
List below all materials in floor deck, including carpet but not floor joists, starting from uppermost surface and working down.

Insert R value for each component from Table 1 (p. 15)

Material	Thickness (Inches)	R Value
Interior surface	—	0.68
Interior surface	—	.68
	Total R value	

FILL IN AT JOB SITE

[ ] Floor area (from building description) sq.ft. **x** [ ] Floor exposure factor **x** [ ] District heating factor **÷** [ ] Total R value **=** [ ] Heating Units Required

Potential Savings on Floor Heat Losses
Floors can sometimes be insulated to reduce heat loss but this is often difficult; where water pipes are below the floor, freezing problems may occur during very cold spells. However, every floor should be protected from drafts, so that it has a floor exposure factor of 0.5. With this exposure factor for this building, the heat loss through the floor would be:

[ ] Floor area from above sq.ft. **x** [0.5] Floor exposure factor **x** [ ] District heating factor **÷** [ ] Total R value from above **=** [ ] Potential heating units

Subtract the potential heating units from those now required and enter here →

Type of Heat Loss	Heating Units Required	Potential Heating Savings	Proposed Changes to Structure	Heating Units to be Saved
Conduction Through Floors				

Heat Losses by Conduction Through Ceilings

Area of Ceiling
(Take area of upstairs ceiling in a two-story house)

Ceiling area will normally be the same as floor area (from building description sheet)

[ ]
Distance between joists/rafters:

Material	Thickness (inches)	R Value
Inside surface	—	0.68
Inside surface (0.68)	—	
— OR —		
Outside surface (0.17)	—	
	Total R value	[ ]

FILL IN AT JOB SITE

[ ] Ceiling area sq.ft. X [ ] District heating factor ÷ [ ] Total R value = [ ] Heating units required

Potential Savings by Insulation of Ceilings

A well-insulated ceiling (with 6 inches of insulation) should have an R value of 20. If the R value were 20 for this building, the ceiling heat loss would be:

[ ] Ceiling area sq.ft. X [ ] District heating factor ÷ [20] Total R value = [ ] Potential heating units

Subtract the potential heating units from those now required and enter here →

Type of Heat Loss	Heating Units Required	Potential Heating Savings	Proposed Changes to Structure	Heating Units to be Saved
Conduction Through Ceilings				

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Heat Losses by Conduction Through Single-Glass Windows

Area of Single Glass Windows:
(Assuming R = 1 for single glass)

If none, enter 0 and go to next sheet on double windows and doors

Width	x	Height	x	Number	=	Area
				Total sq.ft.		

Total sq.ft.	x	District heating factor	=	Heating units required

Potential Saving by Double Glazing

Double glazing or adding storm windows will cut the heat loss by half, so divide heating units by two, and enter here

Type of Heat Loss	Heating Units Required	Potential Heating Savings	Proposed Changes to Structure	Heating Units to be Saved
Conduction Through Single-Glass Windows				

Heat Losses by Conduction Through Double-Glass or Plastic-Covered Windows and Through Doors

Area of Double Glass and Doors

(Assuming R = 2 for these units)

Width	x	Height	x	Number	=	Area
				Total sq.ft.		

	x		÷	2	=	
Total sq.ft.		District heating factor		R value		Heating units required

Potential Savings

Triple glazing of windows can be done but is not usually practical. If no change were made in the windows, the potential saving would be 0 heating units and should be entered here

(If windows were triple glazed, the R value would be approximately 3, and the potential savings would be one-third of the "Heating Units Required.")

Type of Heat Loss	Heating Units Required	Potential Heating Savings	Proposed Changes to Structure	Heating Units to be Saved
Conduction through Doors & Double-Glass Windows				

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Heat Losses by Conduction Through Walls

R Value of Outside Walls

List below all materials in walls, starting from inside and including air spaces within the wall. Insert R value for each component from Table 1.

Material	Thickness (inches)	R Value
Interior surface	—	0.68
Outside surface	—	.17
	Total R value	

FILL IN AT JOB SITE

[ ] Total perimeter of outside wall ft. x [ ] Total height of outside wall ft. = [ ] Gross wall area sq.ft

[ ] Gross wall area sq.ft — [ ] Total area of all windows and doors (from previous two pages) sq.ft. = [ ] Net wall area sq.ft.

[ ] Net wall area x [ ] District heating factor ÷ [ ] Total R Value = [ ] Heating units required

Potential Savings by Insulation

Well-insulated walls should have an R value of 15. If this were so for this building, the wall heat loss would be:

[ ] Net wall area (from box above) x [ ] District heating factor ÷ [15] R value = [ ] Potential heating units

Subtract the potential heating units from those now required and enter here →

Type of Heat Loss	Heating Units Required	Potential Heating Savings	Proposed Changes to Structure	Heating Units to be Saved
Conduction Through Walls				

Summary Table

Use the instructions on page 11 of the Home Weatherization Manual to assess which potential savings can be obtained most successfully.

Fill out the following Summary Table by entering the "Heating Units Required" and the "Potential Heating Savings" from the corresponding tables at the bottom of pages 4-9. Then, write in the "Proposed Changes" and "Heating Units to be Saved" by such changes.

Heat Requirement Estimates (Annual Heating Units Needed)

Type of Heat Loss		Heating Units Required	Potential Heating Savings	Proposed Changes to Structure	Heating Units to be Saved
Infiltration	From Page 4				
Conduction Through Floors	Page 5				
Conduction Through Ceilings	Page 6				
Conduction Through Single-Glass Windows	Page 7				
Conduction Through Doors & Double-Glass Windows	Page 8				
Conduction Through Walls	Page 9				
	Total				

Use the space below to calculate the quantities and cost of materials needed to make the proposed changes to the building.

Fill in job sheet on opposite page.

Job Sheet A

This Page Is Removable for Use at Job Site

Name _____ Address _____

Type of Materials	Quantity Required	Estimated Cost	Location Where Materials Are To Be Installed (Walls, Ceiling, etc.)	Installation Figure No.	Special Instructions

(Insert Carbon Paper Under Table at Top of Page Only)

Map or directions for locating home:

FILL IN AT JOB SITE

Work record

Activity	Date	Supervisor	Comments
Order materials	_____	_____	_____
Install materials	_____	_____	_____

Job Sheet B

This Page is Retained With Job Book as Permanent Record

Type of Materials	Quantity Required	Estimated Cost	Location Where Materials Are To Be Installed (Walls, Ceiling, etc.)	Installation Figure No.	Special Instructions

Total Cost ☐

Pay-off Time

This is the number of seasons for fuel savings to pay off the cost of weatherization.

$$\frac{\square \text{ Total cost (from job sheet above)}}{\square \text{ Fuel factor} \times \square \text{ Total heating units saved} \times \square \text{ Price of fuel per gal, cu.ft., kWh, cord}} = \square \text{ "Pay-off" time (heating seasons)}$$

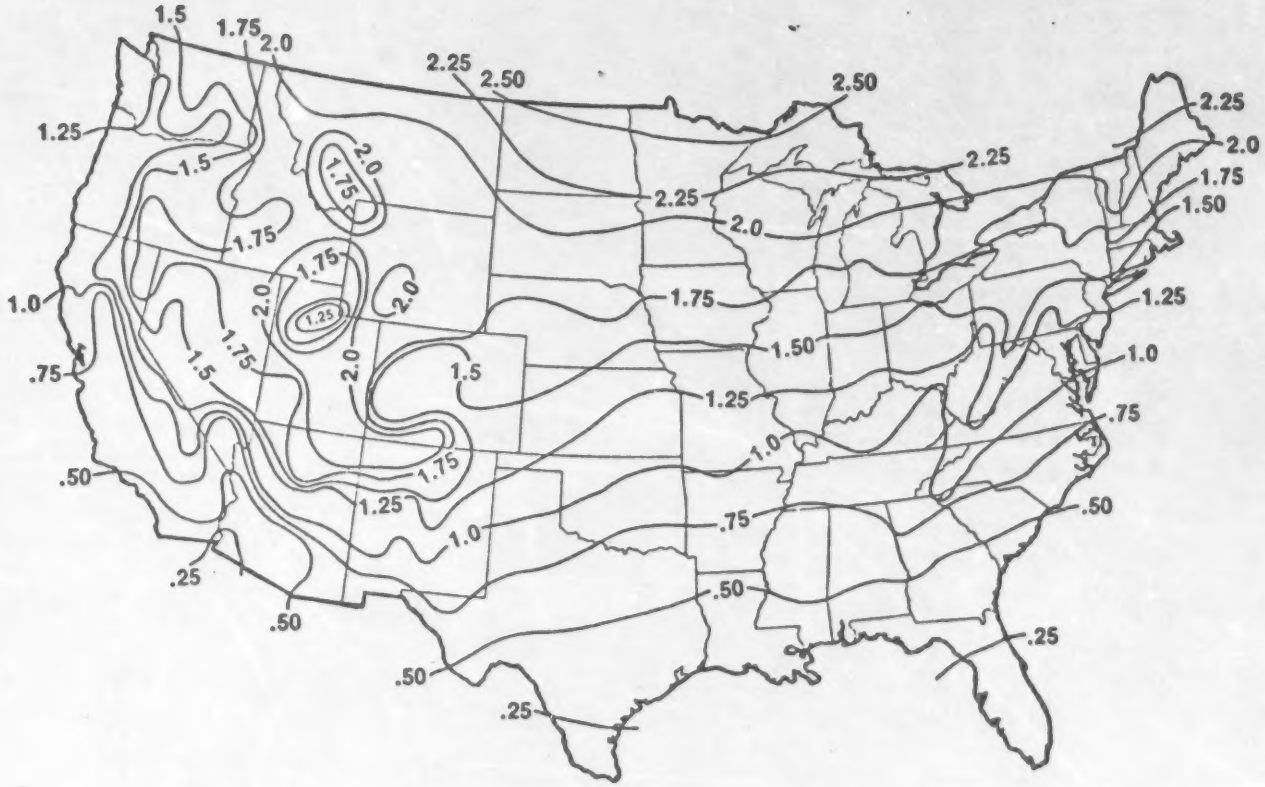
Fuel factor
Fuel oil = 1
Natural gas = 120
Electricity = 30
Wood = .01

Total heating units saved (from page 10)

Price of fuel per gal, cu.ft., kWh, cord

"Pay-off" time (heating seasons)

DISTRICT HEATING FACTOR FOR THE UNITED STATES



63

72

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Table 1: Insulation Value of Common Materials

This list is not intended to include all types of building materials, but only materials commonly used in residences. If necessary, select the material most similar, and the resulting values will not substantially affect the calculation.

MATERIAL	THICKNESS (Inches)	R VALUE
Air Film and Spaces:		
Air space, bounded by ordinary materials	¾ or more	.91
Air space, bounded by aluminum foil	¾ or more	2.17
Exterior surface resistance	—	.17
Interior surface resistance	—	.68
Masonry:		
Sand and gravel concrete block	8	1.11
	12	1.28
Lightweight concrete block	8	2.00
	12	2.13
Face brick	4	.44
Concrete cast in place	8	.64
Building Materials — General:		
Wood sheathing or subfloor	3/4	1.00
Fiber board insulating sheathing	3/4	2.10
Plywood	5/8	.79
	1/2	.63
	3/8	.47
Bevel-lapped siding	1/2 x 8	.81
	3/4 x 10	1.05
Vertical tongue and groove board	3/4	1.00
Drop siding	3/4	.94
Asbestos board	1/4	.13
3/8" gypsum lath and 3/8" plaster	3/4	.42
Gypsum board (sheet rock)	3/8	.32
Interior plywood panel	1/4	.31
Building paper	—	.06
Vapor barrier	—	.00
Wood shingles	—	.87
Asphalt shingles	—	.44
Linoleum	—	.08
Carpet with fiber pad	—	2.08
Hardwood floor	—	.71
Insulation Materials (mineral wool, glass wool, wood wool):		
Blanket or batts	1	3.70
	3 1/2	11.00
	6	19.00
Loose fill	1	3.33
Rigid insulation board (sheathing)	3/4	2.10
Windows and Doors:		
Single window	—	approx. 1.00
Double window	—	approx. 2.00
Exterior door	—	approx. 2.00

Source: ASHRAE Guide and Data Book.

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FIGURE 1.1 BREAKDOWN OF HEATING AND COOLING LOADS FOR CHARACTERISTIC HOUSE USED IN HUD STUDY

COMPONENTS	% OF HEATING LOAD	% OF COOLING LOAD
CEILING	3.7	2.3
FLOOR	2.2	2.4
TOTAL WINDOW	13.6	4.1
TOTAL DOOR	1.4	0.4
TOTAL WALL	23.9	14.2
INFILTRATION LOAD	55.2	41.5
INTERNAL LOAD	--	35.1
	100.0	100.0

FIGURE 1.2

BUILDING CODE CHECKLIST

ITEM	CODE REQUIREMENTS		CAN YOU MEET IT?	
	YES	NO	YES	NO
1. Minimum area of lot (lot size)				
2. Number of families permitted				
3. Minimum or maximum house area				
4. Building height and set-back restrictions				
5. Foundation type (Is masonry required?)				
6. Is post and beam framing permitted?				
7. Is grade stamped lumber required for framing (i.e., new and kiln dried)?				
8. Minimum room sizes				
9. Minimum door sizes and number of exists				
10. Window sizes and ventilation requirements				
11. Forced ventilation for kitchen and baths				
12. Fire retardant enclosure for exitways				
13. Fire alarm system				
14. Riser and tread sizes for stairs				
15. Minimum insulation requirements				
16. Chimney clearances (Is prefab allowed?)				
17. Can owner finish a shell by contractor?				
18. Can attic or some rooms be left unfinished?				

The above list is by no means comprehensive. It is intended to call to your attention the most likely code restrictions that might adversely affect your construction of a house or remodeling of an existing building.

FIGURE 2.1

SUGGESTED SUN ORIENTATION

	N	NE	E	SE	S	SW	W	NW
Bedrooms	X	X	X	X	X	X		
Living				X	X	X	X	
Dining			X	X	X	X	X	
Kitchen			X	X	X	X		
Library	X	X						X
Laundry	X	X						X
Play				X	X	X	X	
Drying yd.				X	X	X	X	
Bathrooms	X	X	X	X	X	X	X	X
Utility	X	X						X
Garage	X	X	X	X	X	X	X	X
Workshop	X	X						X
Terraces			X	X	X	X	X	
Sun Porch				X	X	X	X	

FIGURE 2.2

K FACTORS FOR COMMON BUILDING MATERIALS

MATERIAL	THICKNESS	K FACTOR
CORK BOARD	1"	0.27
FIBERGLASS	1"	0.27
GLASS FOAM	1"	0.40
POLYSTYRENE FOAM	1"	0.15
ROCK WOOL	1"	0.29
FIR	1"	0.67
PINE, SOFT	1"	0.86
PARTICLE BOARD	1"	0.50
SAWDUST	1"	0.41
BRICK, FACE	1"	10.00
BRICK, COMMON	1"	5.00
GYPSUM WALL BOARD	1"	0.70
STONE	8"	0.70
STONE	12"	0.50
CINDER BLOCK	8"	0.50
	12"	0.35
CONCRETE, BLOCK	8"	0.55
	12"	0.45
CONCRETE POURED	8"	0.70
	12"	0.50

FIGURE 2.3

Resistance Values of Structural and Finish Materials, Insulations, Air Spaces, and Surface Films*

Wood bevel siding, 1/2 x 8, lapped	R-0.81
Wood siding shingles, 16", 7½" exposure	R-0.87
Asbestos-cement shingles	R-0.03
Stucco, per inch	R-0.20
Building paper	R-0.06
1/2" nail-base insul. board sheathing	R-1.14
1/2" insul. board sheathing, regular density	R-1.32
25/32" insul. board sheathing, regular density	R-2.04
1/4" plywood	R-0.31
3/8" plywood	R-0.47
1/2" plywood	R-0.62
5/8" plywood	R-0.78
1/4" hardboard	R-0.18
Softwood, per inch	R-1.25
Softwood board, 3/4" thick	R-0.94
Concrete blocks, three oval cores	
Cinder aggregate, 4" thick	R-1.11
Cinder aggregate, 12" thick	R-1.89
Cinder aggregate, 8" thick	R-1.72
Sand and gravel aggregate, 8" thick	R-1.11
Lightweight aggregate (expanded clay, shale, slag, pumice, etc.), 8" thick	R-2.00
Concrete blocks, two rectangular cores	
Sand and gravel aggregate, 8" thick	R-1.04
Lightweight aggregate, 8" thick	R-2.18
Common brick, per inch	R-0.20
Face brick, per inch	R-0.11
Sand-and-gravel concrete, per inch	R-0.08
Sand-and-gravel concrete, 8 inches thick	R-0.64
1/2" gypsumboard	R-0.45
5/8" gypsumboard	R-0.56
1/2" lightweight-aggregate gypsum plaster	R-0.32
25/32" hardwood finish flooring	R-0.68
Asphalt, linoleum, vinyl, or rubber floor tile	R-0.05
Carpet and fibrous pad	R-2.08
Carpet and foam rubber pad	R-1.23
Asphalt roof shingles	R-0.44
Wood roof shingles	R-0.94
3/8" built-up roof	R-0.33

Glass	
Single glass (winter)	U = 1.13
Single glass (summer)	U = 1.06
Insulating glass (double)	
1/4" air space (winter)	U = 0.65
1/4" air space (summer)	U = 0.61
1/2" air space (winter)	U = 0.58
1/2" air space (summer)	U = 0.56
Storm windows	
1" to 4" air space (winter)	U = 0.56
1" to 4" air space (summer)	U = 0.54

Insulation	
2" – 2½" thick	R-7.00
3" – 4" thick	R-11.00
5" – 7" thick	R-19.00

Air Spaces (3/4")	
Heat flow UP	
Non-reflective	R-0.87
Reflective, one surface	R-2.23
Heat flow DOWN	
Non-reflective	R-1.02
Reflective, one surface	R-3.55
Heat flow HORIZONTAL	
Non-reflective (also same for 4" thickness)	R-1.01
Reflective, one surface	R-3.48
Note: The addition of a second reflective surface facing the first reflective surface increases thermal resistance values of an air space only 4 to 7 per cent.	
Surface Air Films	
INSIDE (still air)	
Heat flow UP (through horizontal surface)	
Non-reflective	R-0.61
Reflective	R-1.32
Heat flow DOWN (through horizontal surface)	
Non-reflective	R-0.92
Reflective	R-4.55
Heat flow HORIZONTAL (through vertical surface)	
Non-reflective	R-0.68
OUTSIDE	
Heat flow any direction, surface any position	
15 mph wind (winter)	R-0.17
7.5 mph wind (summer)	R-0.25

Example calculations
(to determine the U value of an exterior wall)

Wall Construction	Uninsulated Wall Resistance	Insulated Wall Resistance
Outside surface (film), 15 mph wind	0.17	0.17
Wood bevel siding, lapped	0.81	0.81
½" ins. bd. sheathing, reg. density	1.32	1.32
3½" air space	1.01	
R-11 insulation		11.00
½" gypsumboard	0.45	0.45
Inside surface (film)	0.68	0.68
Totals	4.44	14.43

For uninsulated wall, $U = \frac{1}{R} = \frac{1}{4.44} = U = 0.22$

Therefore, heat loss for the above uninsulated wall section at a +10° F. outside design temperature is equal to 0.22 x 60 (or 70-10) equals 13.2 Btuh per sq. ft. of wall section.

For insulated wall, $U = \frac{1}{R} = \frac{1}{14.43} = U = 0.07$

Therefore, heat loss for the above insulated wall section at a + 10° F. outside design temperature is equal to 0.07 x 60 (or 70-10) equals 4.2 Btuh per sq. ft. of wall section.

* Additional resistance values can be obtained from ASHRAE Handbook of Fundamentals published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

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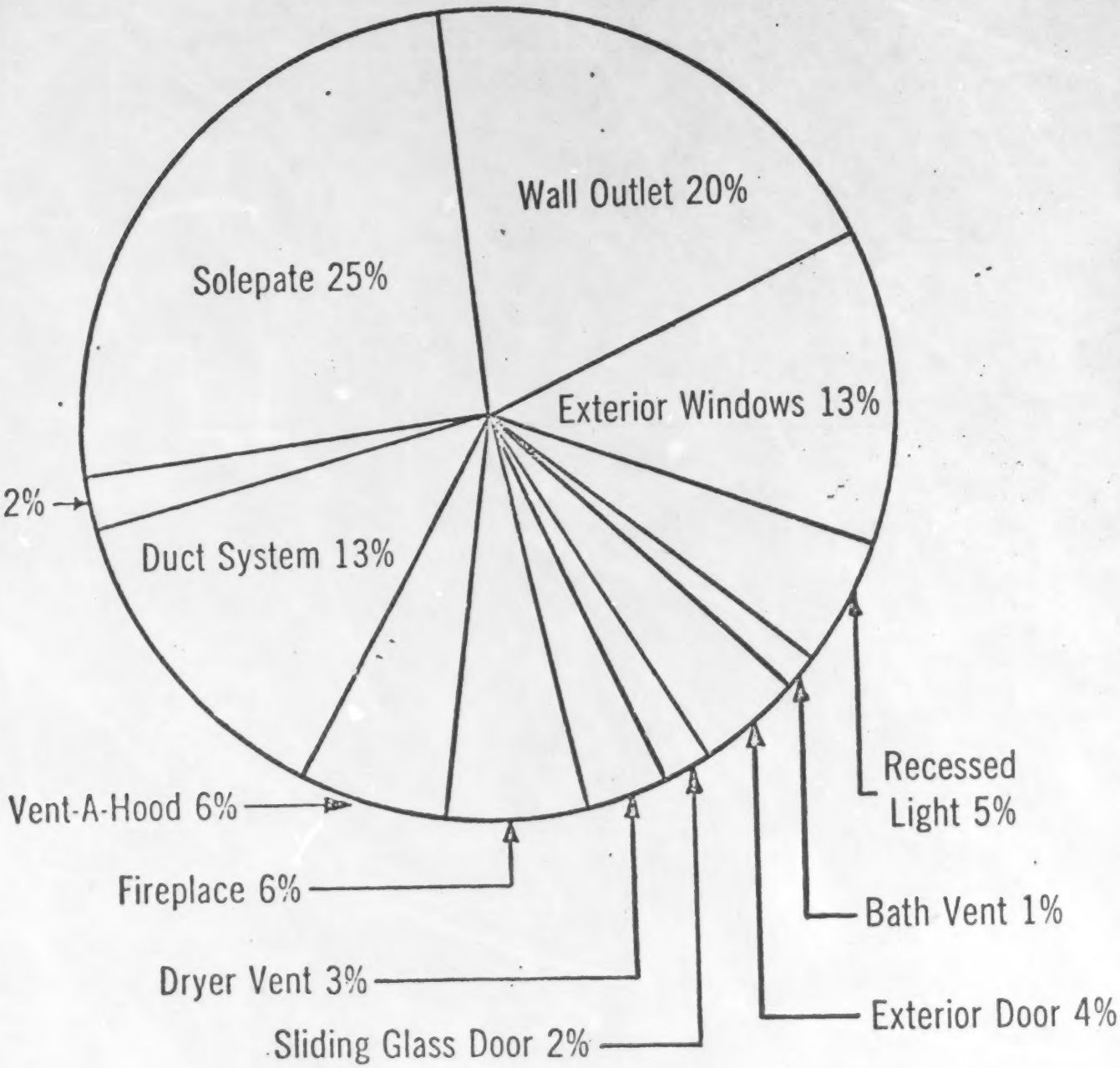
FIGURE 3.1

AIR LEAKAGE TEST RESULTS FOR AN AVERAGE SIZE HOME OF 1728 SQ. FT.



SOURCE: TEXAS POWER & LIGHT COMPANY